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Ship Hydromechanics Department

BERING SEA WAVE AND ICE MEASUREMENTS IN SUPPORT OF ARCTIC WEST WINTER 1986

by

William L. Thomas III

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DTRC/SHD-1212-03 Bering Sea Wave and Ice Measurements in Support of Arctic West Winter 1986

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Arctic West Winter 1986 (AWW-86) was conducted aboard USCGC POLAR SEA (WAGB-11) from 1 April to 30 April 1986 in the Northeast Pacific Ocean and Southern Bering Sea. During the first leg of the trial, three open ocean wave measurements were made using Delft University wave buoys. Five wave measurements were made during the remainder of the trial in the Bering Sea. Wave measurements were compared with Global Spectral Ocean Wave Model (GSOWM) forecasts which were provided by the Fleet Numerical Oceanography Center in Monterey, California. Ice edge observations were compared with ice edge forecasts provided by the Naval Polar Oceanography Center in Suitland, Maryland. Observations related to ice accretion were compared to Wise and Comisky nomogram predictions.

Interviews were conducted with officers and crewmembers aboard USCGC POLAR SEA in an effort to document experience in cold weather operations which may be beneficial to the U.S. Navy.

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ABSTRACT

Arctic West Winter 1986 (AWW-86) was conducted aboard USCGC POLAR SEA (WAGB-11) from 1 April to 30 April 1986 in the Northeast Pacific Ocean and Southern Bering Sea. During the first leg of the trial, three open ocean wave measurements were made using Delft University wave buoys. Five wave measurements were made during the remainder of the trial in the Bering Sea. Wave measurements were compared with Global Spectral Ocean Wave Model (GSOWM) forecasts which were provided by the Fleet Numerical Oceanography Center in Monterey, California. Ice edge observations were compared with ice edge forecasts provided by the Naval Polar Oceanography Center in Suitland, Maryland. Observations related to ice accretion were compared to Wise and Comisky nomogram predictions.

Interviews were conducted with officers and crewmembers aboard USCGC POLAR SEA in an effort to document experience in cold weather operations which may be beneficial to the U.S. Navy.

ADMINISTRATIVE INFORMATION

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INTRODUCTION

Cold weather regions have become an area of interest to the U.S. Navy in recent years. In addition to cold temperatures, some of the more prominent environmental hazards encountered in northern waters include heavy sea states, floating ice, and superstructure icing. Weather prediction products, which forecast wave spectra and ice edge location on a global basis, have been developed but have not extensively been tested by Navy surface forces in northern latitudes. An algorithm which accurately predicts the rate of ice accretion onboard Navy ships

has not been developed because most information compiled and analyzed applies to fishing vessels, which are much smaller than the typical warship.[1]

The April 1986 deployment of the USCGC POLAR SEA (WAGB-11) to the Bering Sea on Arctic West Winter 1986 (AWW-86) provided the opportunity to measure ocean waves in areas of open ocean and floating ice. Observations related to the location of the ice edge and superstructure icing were also recorded. The objective of this report is to compare in situ measurements with prediction products.

WAVE MEASUREMENTS

STATEMENT OF PROBLEM

Forecasts of directional wave spectra are available to Navy ships from the Fleet Numerical Oceanography Center (FNOC) in Monterey, California through use of the Global Spectral Ocean Wave Model (GSOWM). Forecasts are provided to ships in message format at times 0000Z and 1200Z daily for global locations which are spaced every 2.5 degrees latitude and longitude. Although GSOWM is somewhere between a first and second generation wave model, it has yet to be fully validated. Therefore, the need exists to make an operational comparison of measured waves and GSOWM forecasts in northern latitudes.

APPROACH

A wave measurement trial was conducted aboard USCGC POLAR SEA (WAGB-11) during the AWW-86 deployment. This deployment took place from 7 April to 30 April 1986 in two phases. The first phase involved an open ocean transit from Seattle, Washington to Dutch Harbor, Alaska from 7 to 14 April. The second phase was conducted in the Bering Sea from 15 to 30 April.

Wave height measurements were conducted along the ship's route using the Delft Disposable Wave Buoy, though in all cases the buoy was recovered. The buoy deployments were made at times of opportunity which did not otherwise interfere

with POLAR SEA's operating schedule. As a result, neither ship's route nor time schedule were modified in favor of GSOWM grid points. This procedure was followed to provide realistic results in view of the fact that Navy ships do not deliberately pass through GSOWM grid points. The wave spectral densities calculated from the Delft wave buoy measurements were compared with GSOWM spectra for the grid point nearest to the ship's position at the time of the buoy measurement.

INSTRUMENTATION

The primary instrumentation for the wave measurements were two disposable wave buoys which were developed by the Ship Hydromechanics Laboratory of the Delft University of Technology in Delft, Netherlands. The Delft Disposable Buoy differs from other wave buoys in that it is sufficiently small to allow deployment by one person without crane assistance. Thus, it is easy to deploy with minimum impact to ship operations. The small size and light weight of the spherical buoy, however, does not permit the measurement of wave directionalities. A point spectrum is provided instead. Significant characteristics of the Delft buoy are listed in Table 1. Delft buoys are constructed of fiberglass and steel. The buoy's sphere contains a battery pack, accelerometer, transmitter, and electronics package.[2] The Delft Disposable Buoy transmitted continuous data of vertical acceleration which were recorded on analog tape by DTRC instrumentation aboard USCGC POLAR SEA.

Buoy measurement locations are displayed in Fig. 1 with a corresponding summary of buoy deployments listed in Table 2.

DATA ANALYSIS

Analog time history data of Delft wave buoy measurements were digitized using routines developed by DTRC Code 1561. Analysis routines utilize Fast Fourier Transform processing to calculate spectral densities. Calculated buoy spectra and GSOWM spectra predictions are shown in Figs. 2 through 9.

Ninety five percent confidence bands for the wave buoy measurements were calculated utilizing Reference 3 statistical techniques which apply to Fast Fourier Transform processing. Briefly stated, for spectral density calculations:

$$\frac{\nu\, S(f)}{\chi^2_{\nu(100-\alpha)/2}} < S'(f) < \frac{\nu\, S(f)}{\chi^2_{\nu(100+\alpha)/2}}$$

where

$S'(f)$ = true value of spectral density

$S(f)$ = calculated spectral density

ν = degrees of freedom

χ^2 = chi-square value

α = percent confidence level

For significant wave height measurements:

$$\left(\frac{\nu}{\chi^2_{\nu(100-\alpha)/2}}\right)^{1/2} (\tilde{\zeta}_w)_{1/3} < (\tilde{\zeta}_w')_{1/3} < \left(\frac{\nu}{\chi^2_{\nu(100+\alpha)/2}}\right)^{1/2} (\tilde{\zeta}_w)_{1/3}$$

where

$(\tilde{\zeta}_w')_{1/3}$ = true value of significant wave height

$(\tilde{\zeta}_w)_{1/3}$ = calculated significant wave height

ν = degrees of freedom

χ^2 = chi square value

α = percent confidence level

DISCUSSION

Northeast Pacific Ocean Wave Measurements

The wave spectral density peaks and significant wave heights as predicted by GSOWM fell within the 95 percent measurement confidence bands in one out of the three North Pacific buoy measurements, see Figs. 2 through 4. The differences

between the Delft wave buoy measurements and the GSOWM spectra shown in Figs. 3 and 4, indicate that the predicted values for wave energy were much higher than the measured energy. Very good peak frequency agreement between the wave buoy measurement and GSOWM is displayed in Figs. 2 and 4. In Fig. 3 the GSOWM peak occurs at a lower frequency than the wave measurement. A difference in location and time between the Delft wave buoy measurements and the GSOWM predictions did not appear to be factors which induced differences. This may be implied since the greatest difference in location and time between a buoy measurement and the GSOWM prediction occurred during the first buoy measurement which showed good agreement with GSOWM, see Fig. 2 and Table 2.

Bering Sea Wave Measurements

Little agreement was found between GSOWM spectral predictions and Delft wave buoy measurements for all four wave measurements taken in the Bering Sea, see Figs. 5 through 8. In all cases, the magnitudes of the predictions were well outside the 95 percent confidence limits of the measured data. In addition, the estimated location of the ice edge with respect to the GSOWM grid point and the buoy measurement position was unique for three of the four wave measurements. As a result, a discussion involving each wave measurement is warranted.

Delft wave measurement number 4 (Fig. 5) occurred at 0000Z 16 April 1986 in the open ocean approximately 85 nautical miles east of St. Paul Island, see Fig. 9. The nearest GSOWM grid point was approximately 60 nautical miles to the north of the measurement point, which was also approximately 15 nautical miles to the south of the forecasted ice edge. Since westerly winds and seas were observed at the time of the wave measurement, the ice edge does not seem to have been in a position which would have influenced the seas at either the GSOWM grid point or the buoy measurement point.

Delft wave measurements number 6, 7, and 8 were made in seas containing 7/10 concentration of sea ice whose thickness varied between 1 and 2 meters. Visual observations made during these wave measurements indicated that the floating ice had a dampening effect on the waves, reducing the magnitude of wave energy and filtering out higher frequency waves.

Delft wave measurements number 6 and 7 occurred at 1800Z and 2000Z 27 April 1986 in ice of 7/10 concentration as shown in Fig. 10. The nearest GSOWM grid point was approximately 70 nautical miles to the southeast, in open water. With seas propagating from the open ocean to the pack ice, it is of no surprise that the GSOWM forecast differs from the wave measurement. The waves in the measurement region seemed to be subject to a dampening effect which was caused by the floating ice. This dampening effect was not present at the GSOWM grid point. As a result, the open water forecasts were higher in magnitude than the measurements taken in the region of floating ice.

Delft wave measurement number 8 was taken on the GSOWM grid point in ice of 7/10 concentration at 0300Z 29 April 1986. As seen in Fig. 8, the predicted values for wave spectral density and significant wave height were overestimated by [illegible]. This again may be due to a dampening effect which was observed as the waves propagated through the ice.

ICE EDGE FORECASTS

INTRODUCTION

Sea ice data messages were provided by the Naval Polar Oceanography Center in Suitland, Maryland from 15 to 29 April 1986. Ice data messages contained latitude and longitude number pairs which were plotted and connected with a line to produce a plot of the sea ice edge. The sea ice edge was defined as the limit of 1/1[illegible]

greater concentration of ice.[4] Bering Sea ice edge observations were compiled and compared with the sea ice edge forecasts.

APPROACH

Sea ice edge forecasts were plotted as shown in Figs. 11 to 16. Visual observations of the ice edge were extracted from applicable logs maintained by USCGC POLAR SEA. These included the deck log, ice observation log, weather log, and position log from 15 to 29 April 1986. Data in each respective record was verified for agreement with the others. Observed locations of the ice edge were plotted in Figs. 11 to 16 for comparison with the forecasts. Observed ice edge positions are summarized in Table 3.

RESULTS

Specific comparisons between observed and forecasted ice edges are presented in Table 4. When ice forecasts predicted an expansion of the ice edge to the south, comparisons were made between the observed ice edge and the "expanded" location. Observed ice edges, on the average, were found to be approximately 10 nautical miles (nmi) south of the forecasted location. This is considered to be in good agreement since this error falls within the resolution of cloud limited satellite data sources utilized by the Naval Polar Oceanography Center.[5]

DISCUSSION

The sea ice edge data messages were accurate from the scientific point of view because the ice edge positions fell within the resolution of the cloud limited remote sensors. Improvements are recommended to increase the usefulness of ice edge forecasts to operational units. These improvements include upgrading the resolution of remote sensors to increase ice edge definition. A second recommendation would be to increase the frequency of ice edge forecasts supplied to Navy ships

to one per day from one every three days to facilitate the planning of daily operations.

Daily movement of the ice edge can be significant and may have potential impact on scheduled operations of Navy ships. This point was demonstrated on 25 and 26 April 1986. USCGC POLAR SEA crossed the ice edge on a southerly course to open water at time 1326Z on 25 April. The ship proceeded south approximately 10 miles in open water to conduct helicopter operations in the vicinity of Saint Paul Island, see Fig. 15. The ice edge moved approximately 10 nmi to the south during the following 12 hours. At time 0130Z on 26 April, POLAR SEA entered the ice edge within sight of Saint Paul Island, and commenced flight operations. (Icebreakers often lie to in the ice to launch helicopters.) If POLAR SEA had not been an ice reinforced ship, she would have been forced to proceed south to avoid damage from the approaching ice. This sudden movement of the ice edge was not predicted by the sea ice edge forecast which predicted a 5 nmi expansion of the ice edge between 25 and 29 April, see Figs. 14 and 15.

SUPERSTRUCTURE ICING

INTRODUCTION

One hazard which is unique to cold weather climates is the icing of ships. Much attention has been given in recent years to this phenomenon because of the potential danger to ship safety. The sinking of ships, particularly small and medium size fishing vessels, due to icing is not an uncommon occurrence. Soviet reports indicate that approximately 10 vessels are lost annually in northern waters because of icing and larger numbers are placed in distress.[6]

Ice accretion has the potential of causing serious ship handling problems leading to instability. The accumulation of ice raises the center of gravity of a ship and if left unchecked, will cause a significant decrease in stability and

eventual capsizing.[7] The accumulation of ice on antennas makes radio communication difficult and has a detrimental effect on radar systems.

Shipboard icing can result from a variety of causes as indicated in References 8 and 9. These include:

a. Supercooled fog

b. Freezing rain or drizzle

c. Falling snow

d. Freezing sea spray

Soviet statistical analysis of numerous cases of icing of fishing vessels indicate that ice accretion is most often caused by freezing sea spray or the combined action of freezing sea spray and precipitation. This accounted for 91 percent of the icing events as reported by References 10 and 11. The remaining nine percent of reported cases were caused by the freezing of fog droplets or rain.

Superstructure icing is generally thought to occur at air temperatures between -2.2 and -18 degrees Celsius with sea water temperatures less than 6 degrees Celsius and wind speed > = 17 knots.[12] As air and sea temperatures drop and wind speed rise, the probability of icing increases.[13] Table 5 from Reference 6 lists time periods and regions where superstructure icing is likely to occur based on 22 years of data.

STATEMENT OF PROBLEM

One of the more recent and complex nomogram-type forecasting aids listed in Reference 1 has been developed by Wise and Comiskey. These nomograms represent an integrated version of Mertin's diagrams which have been adjusted for the northeast Pacific Ocean and the Bering Sea.[13] Some doubt exists as to whether or not the Wise and Comisky nomograms are applicable to vessels larger than fishing trawlers.[1]

Therefore, a need exists to compare Wise and Comisky icing predictions with observed data.

APPROACH

Measured weather parameters were applied to Wise and Comiskey nomograms to forecast ice accretion rates. Values for forecasted ice thickness were calculated for time periods surrounding icing events by multiplying the minimum values of forecasted ice accretion rates by the elapsed time. Comparisons were made between forecasted ice accretion and observed ice accretion during icing events aboard USCGC POLAR SEA.

RESULTS

Three brief icing events were recorded between 17 and 19 April 1986. These events are summarized in Tables 6 and 7 along with direct comparisons displayed in Figs. 17 and 18. Wise and Comisky forecasts usually overestimated observed values for ice thickness. It is interesting to note at 0300 on 19 April, Wise and Comisky nomograms continued to forecast ice accretion when the observed ice on deck melted for a brief period of time, see Fig. 18.

Significant environmental parameters related to the icing events are listed in Tables 8 and 9. Air and sea temperature parameters are plotted in Figs. 19 and 20. The first icing event occurred at approximately 0200Z on 17 April. Figure 19 indicates that the sea water temperature dropped to -1.4 degrees Celsius and the air temperature dropped to -3.1 degrees Celsius during this time period. The second and third icing events occurred at approximately 1800Z 18 April and 0600Z 19 April, respectively. These events could not easily be correlated to the environmental parameters listed in Table 9 or Fig. 20. A look at this figure raises the question as to why no ice accretion occurred at 1200Z on 19 April when the severest environmental conditions existed.

DISCUSSION

Lack of sea spray seems to answer to the above question. The major lesson learned in this portion of AWW-86 is that in the absence of supercooled fog and atmospheric precipitation, superstructure icing will seldom occur in the absence of sea spray. Each of the documented icing events occurred at times when USCGC POLAR SEA was taking sea spray over the bow. When POLAR SEA changed its course to a direction which did not cause spray across the bow, ice accretion ceased.

The result of this brief survey indicates that existing ice accretion algorithms will never be of sufficient accuracy for operational use unless consideration is given to conditions which cause sea spray to strike the ship. Sea spray on the forecastle deck appears to be related to pitch or perhaps a combination of pitch, roll, heave, and wind. Pitch and roll characteristics which create sea spray in icing situations will be unique for each hull form and, as a result, an ice accretion algorithm for each class of ship must be developed if ice accretion forecasts are to be improved.

ORAL INTERVIEW SUMMARIES

Interviews were conducted with the commanding officer of POLAR SEA and senior crewmembers with experience in the Arctic to address topics applicable to the U.S. Navy. Significant points made during these interviews are summarized in the following paragraphs.

PREDEPLOYMENT CONSIDERATIONS

Prior to a deployment to a cold weather region, each division on a ship must carefully screen maintenance procedures to determine whether or not additions or modifications must be made for cold weather operations. Special attention must be paid to ensure that fuel and lubricants are appropriate for anticipated operating

conditions and temperatures. This will usually require system experts to compare Planned Maintenance System (PMS) procedures with technical manual specifications. If discrepancies are identified, PMS feedback reports must be submitted.

Appropriate materials and equipment such as cold weather clothing, deicing equipment, and cold weather lubricants must be ordered in a timely manner.

Appropriate ice forecast products must be requested from NAVPOLAROCEANCEN SUITLAND, MD. A description of available products is listed in Reference 5.

A trained meteorologist provided on at least one ship per battlegroup is essential for maximum operational success in cold weather regions. A good understanding of the interaction between weather and sea ice dynamics is essential.

Ships dispatched to cold weather regions should be issued extra rations of food to compensate for extra calories consumed by the human body when working in cold climates.

TRAINING NEEDS

Cold weather training should be provided to crewmembers prior to deployment. Possible topics for training include: cold weather survival, prevention and treatment of hypothermia, prevention and treatment of frostbite, and proper use of cold weather clothing. The ship's medical department should obtain appropriate training related to the treatment of cold weather problems.

ICE EDGE

Ice edges are difficult to plot on paper except during instances when the ice is compact along the edge. This usually occurs when the wind is blowing from the open ocean toward the ice. When the wind blows across the ice pack toward the open ocean, the ice edge tends to expand, causing a scattered and nonuniform distribution of ice. As a result, the term "ice edge" is difficult to define. The most

acceptable definition appears to be the demarcation between the open sea and sea ice of any kind, including fast or drifting ice.[4]

The location of the ice edge changes constantly and is most often affected by the wind. Ice observers aboard POLAR SEA claim that the location of the ice edge has been known to change as much as 50 nmi in one day. An approach to the ice edge by a ship which is not ice reinforced should be very cautious and never attempted at night. The entry of an open lead is similar to entering a maze with the exception that there is no guarantee that the lead will remain open. Helicopters should be used to locate the best route for the ship to travel.

Aircraft should be used whenever possible to conduct ice reconnaissance missions. Helicopters, with trained ice observers, perform this mission well. Real time ice edge information will be an asset to operational planning.

SUPERSTRUCTURE ICING

Spray induced icing is the most common cause of ice accretion in northern latitudes. Most ice accretion occurs on forward portions of the ship on the forecastle and superstructure. Green water has the tendency to keep the lower portions of the hull free of ice.

De-icing efforts should commence well before accumulated ice becomes a threat to ship stability. POLAR SEA prepared itself for ice accretion events by dividing crewmembers, which were not actually standing watch, into three sections. The job of each section was to remove ice. The length of each work shift was to be commensurate with weather conditions.

Rotating antennas exposed to the cold should be cycled during each watch to ensure moving parts remain free of ice.

DE-ICING METHODS

The use of baseball bats and ax handles to remove accumulated ice is very effective in many instances. The use of these wooden tools prevents damage to painted metal surfaces.

Fragile equipment should be de-iced using other means such as steam cleaners, brooms, etc.

COLD WEATHER CLOTHING

Commercial Mustang brand exposure suits, insulate gloves with a GORTEX shell, long underwear, and Mukluk type boots were experienced to be useful and practical in cold weather.

CONCLUSION

Successful operation in the cold weather regions will depend on a number of factors including preparation, training, and the ability to cope with adverse environmental conditions. This report briefly touched on three environment factors which may significantly impact on planned events. These factors are sea conditions, ice edge location, and superstructure icing. Prediction tools for these conditions were compared with several in situ measurements. The in situ measurements did not always agree with the predictions. Many more measurements would be required to validate GSOWM or Ice Edge forecasts for accuracy in a statistical sense.

Observations conducted during AWW-86 have shown that weather conditions in the Marginal Ice Zone (MIZ) are very dynamic. The location of the ice edge is of particular interest to naval vessels which are not designed to operate in heavy ice regions. A trained weather/ice observer should be present in each group of ships operating in the MIZ to provide the best possible interpretation of the existing ice and weather situation to the operational commander.

ACKNOWLEDGMENT

The kind cooperation of the USCGC POLAR SEA (WAGB-11) under the able leadership of CAPT John T. Howell made this sea trial possible. The outstanding efforts of CDR Charles G. Boyer, LT James A. Dale and MSTC Michael F. Alles deserve special recognition.

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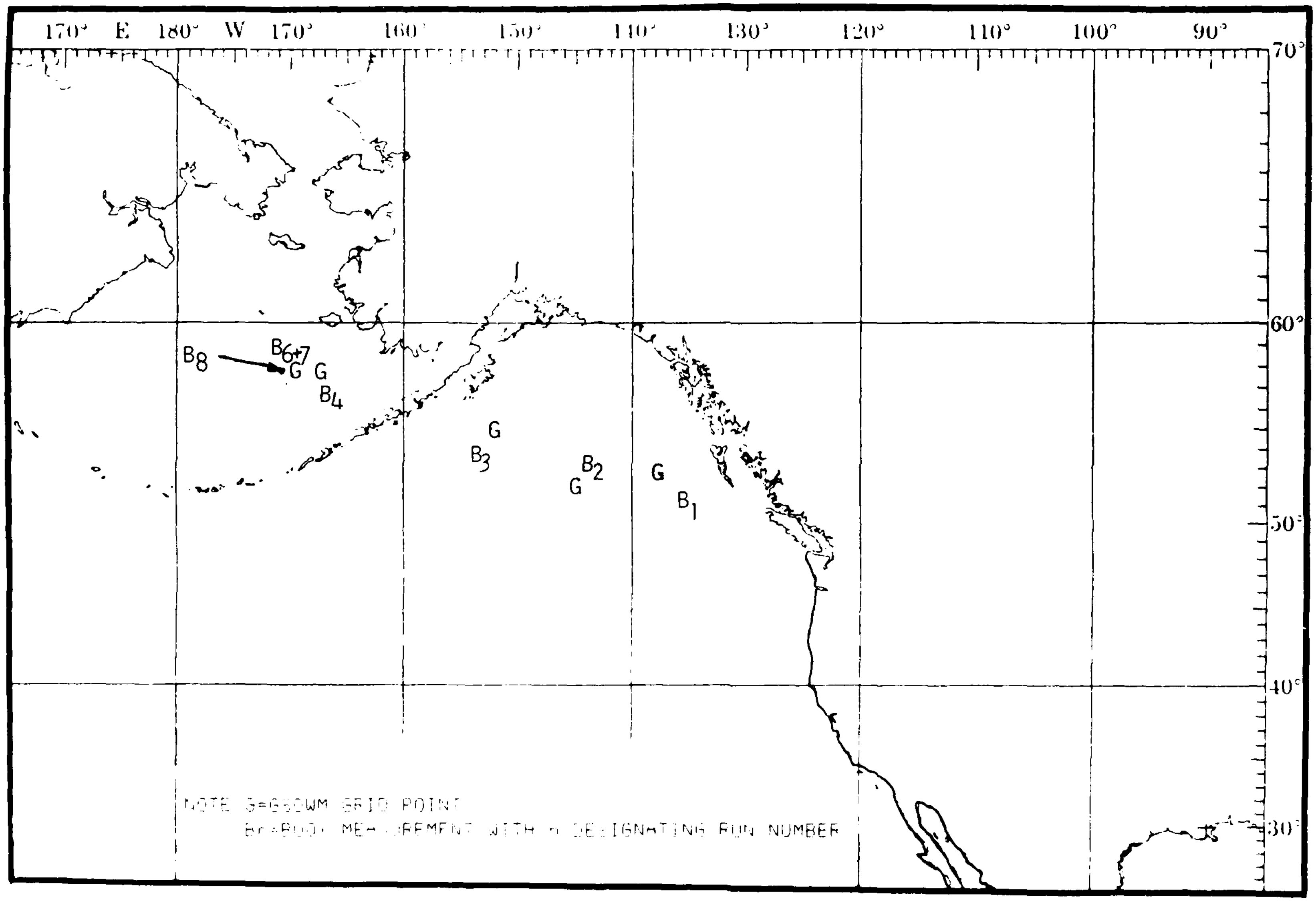
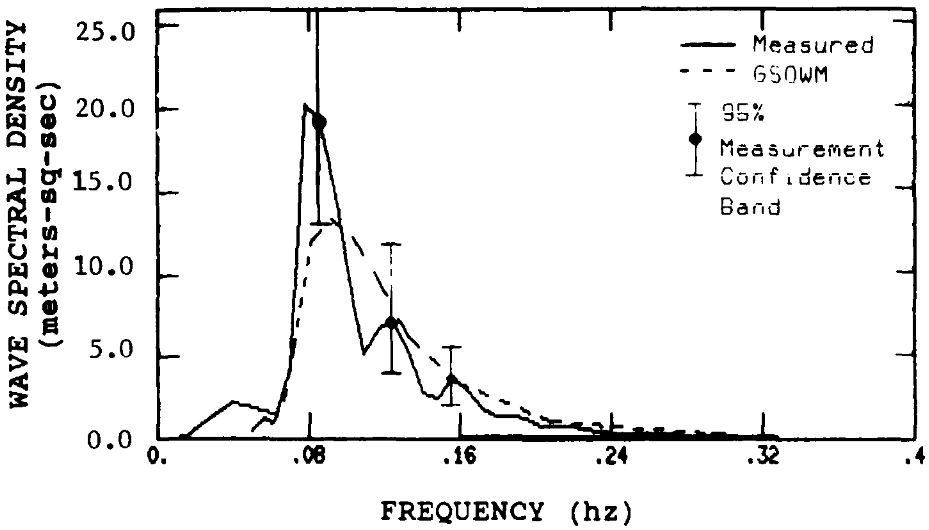


Figure 1 - Delft Wave Buoy measurement locations with corresponding GSOWM grid points.



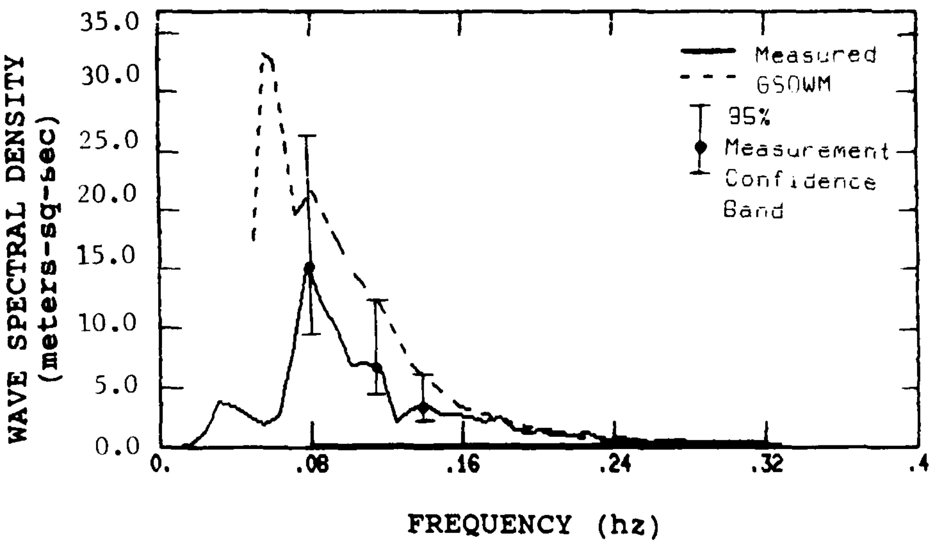
Significant Wave Height

Delft Buoy: 4.1m (+1.3/-.8 m)*

GSOWM: 4.0m

*95% Confidence band.

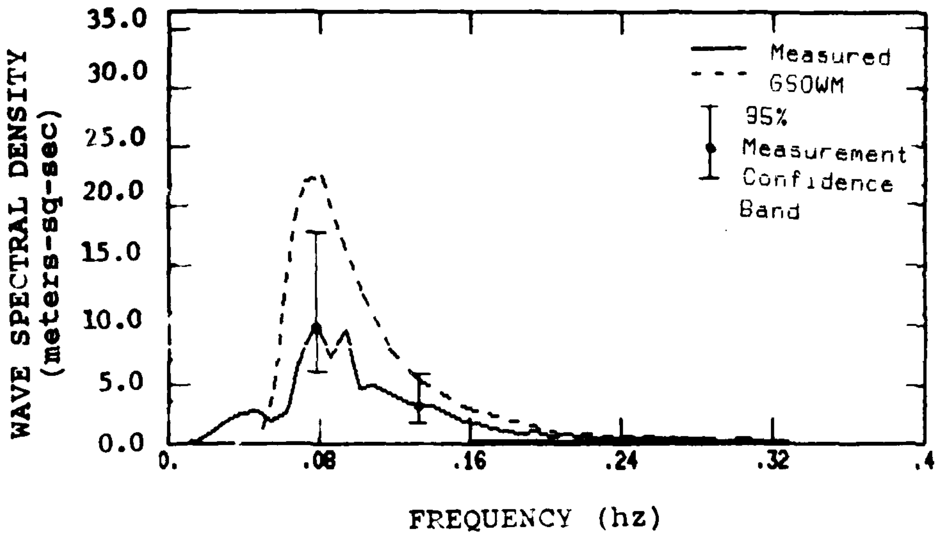
Figure 2 - Comparison between GSOWM wave spectra and wave buoy measured spectra for Buoy Measurement #1.



Significant Wave Height
Delft Buoy: 3.8m (+1.2/-.7 m)*
GSOWM: 5.5m

*95% Confidence band.

Figure 3 - Comparison between GSOWM wave spectra and wave buoy measured spectra for Buoy Measurement #2.



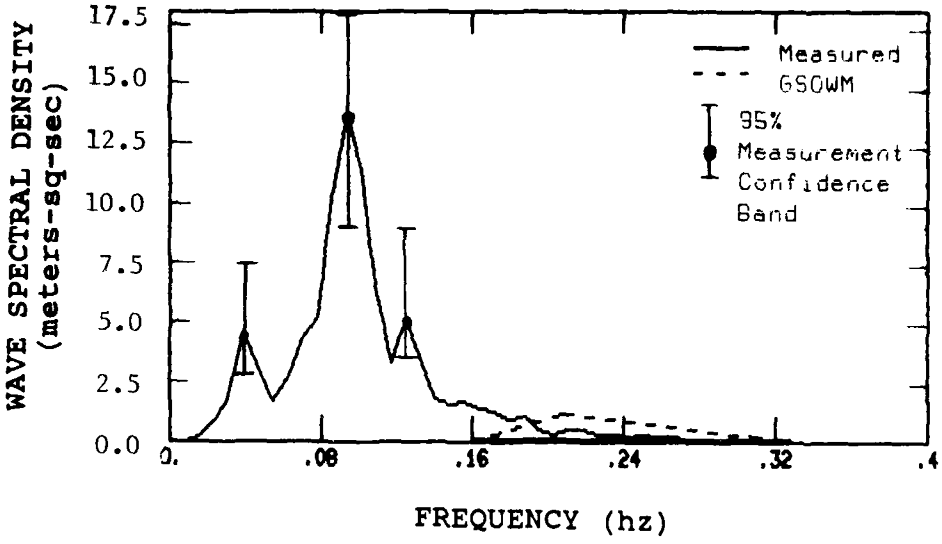
Significant Wave Height

Delft Buoy: 3.4m (+1.1/-.7 m)*

GSOWM: 4.7m

*95% Confidence band.

Figure 4 - Comparison between GSOWM wave spectra and wave buoy measured spectra for Buoy Measurement #3.

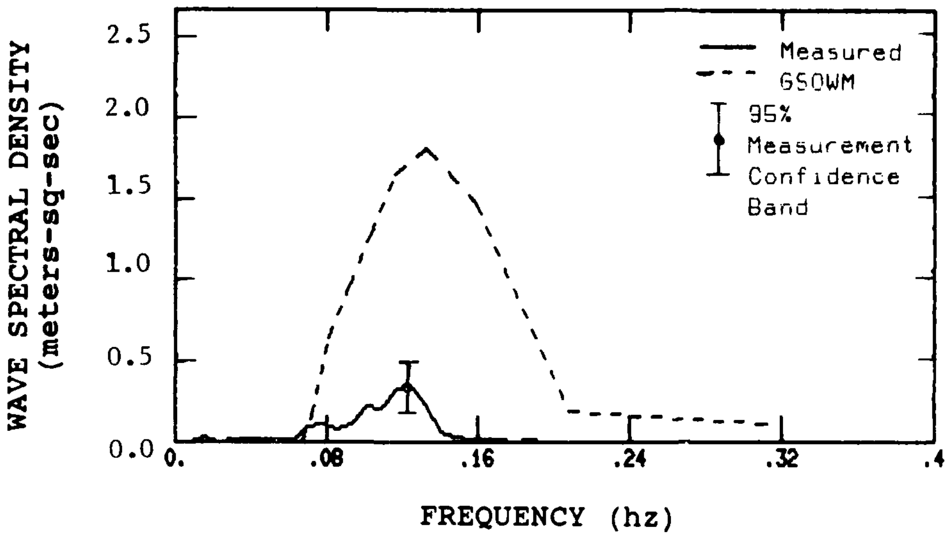


Significant Wave Height

Delft Buoy:	3.4m	(+1.1/-.7 m)*
GSOWM:	1.3m	

*95% Confidence band.

Figure 5 - Comparison between GSOWM wave spectra and wave buoy measured spectra for Buoy Measurement #4.



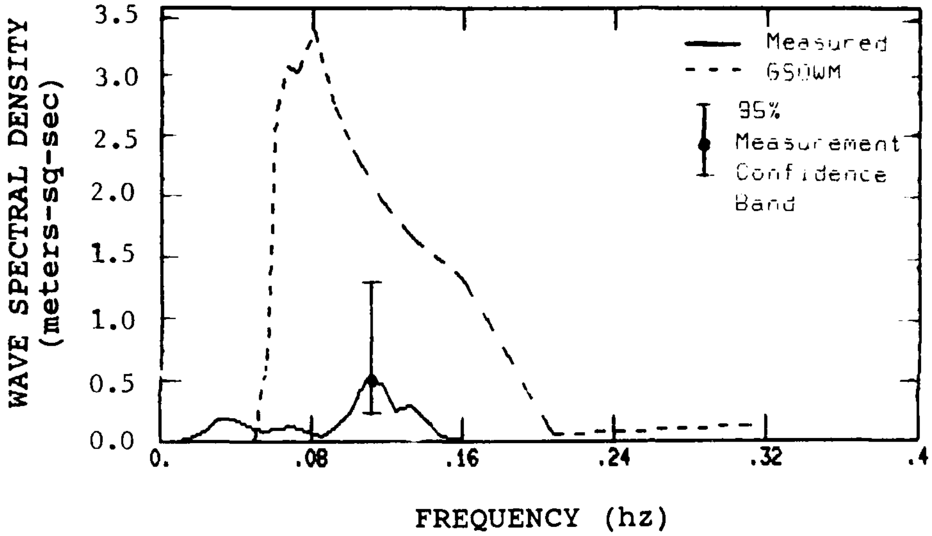
Significant Wave Height

Delft Buoy: 0.5m (+0.2/-0.1m)*

GSOWM: 1.7m

*95% Confidence band.

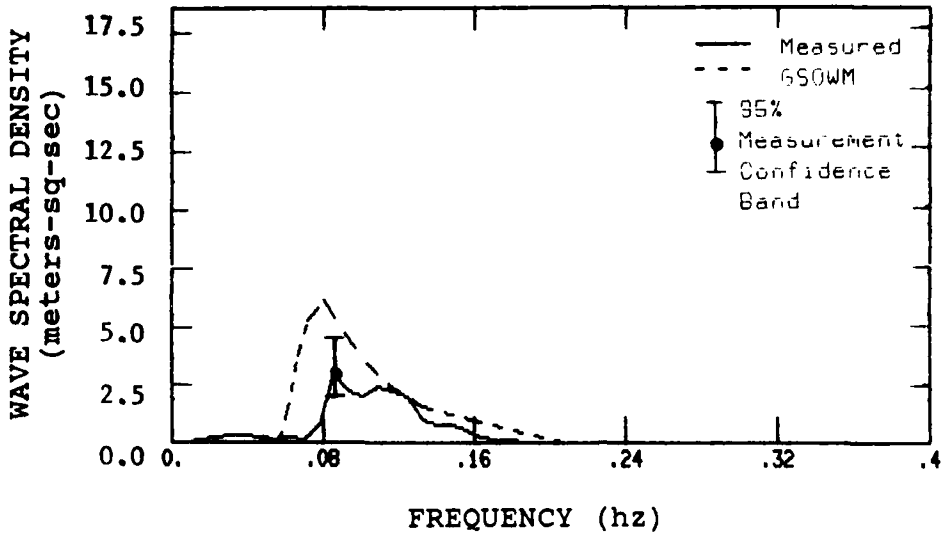
Figure 6 - Comparison between GSOWM wave spectra and wave buoy measured spectra for Buoy Measurement #6.



Significant Wave Height
Delft Buoy: 0.6m (+0.3/-0.2m)*
GSOWM: 2.2m

*95% Confidence band.

Figure 7 - Comparison between GSOWM wave spectra and wave buoy measured spectra for Buoy Measurement #7.



Significant Wave Height

Delft Buoy: 1.5m (+0.3/-0.2m)*

GSOWM: 2.3m

*95% Confidence band.

Figure 8 - Comparison between GSOWM wave spectra and wave buoy measured spectra for Buoy Measurement #8.

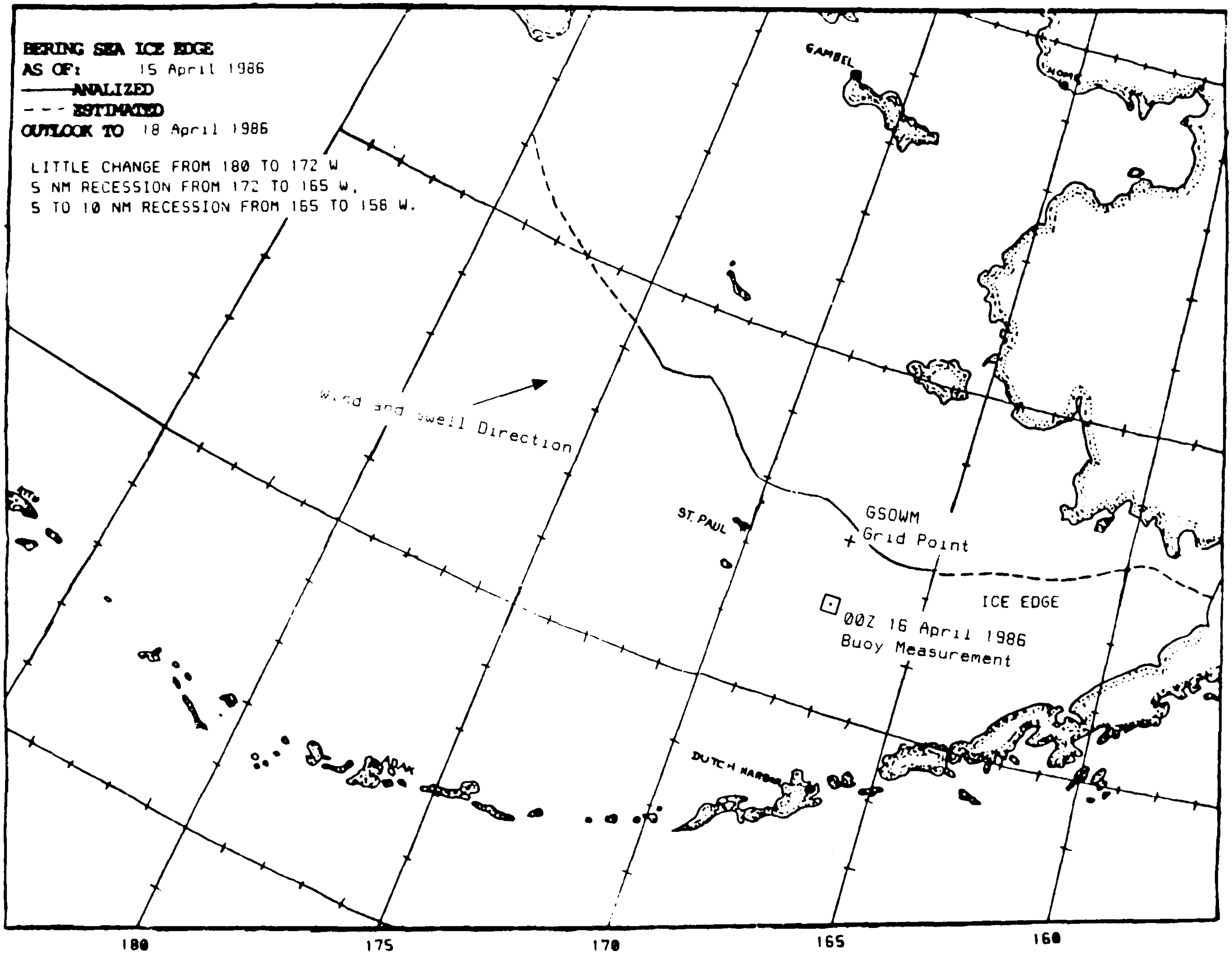


Figure 9 - Buoy measurement location and GSOWM grid point location compared to the forecasted ice edge on 16 April 1986.

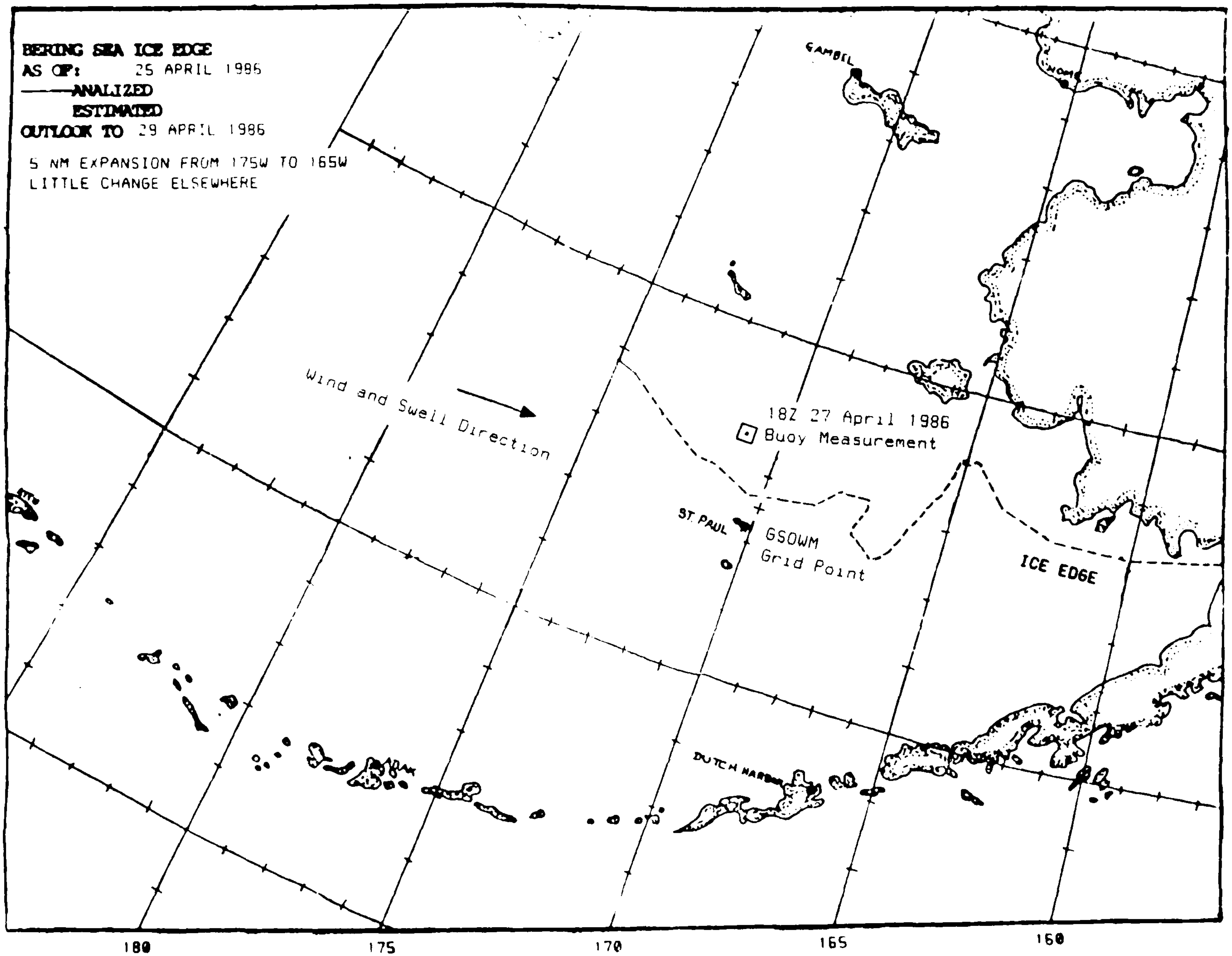


Figure 10 - Buoy measurement location and GSOWM grid point location compared to the forecasted ice edge on 27 April 1986.

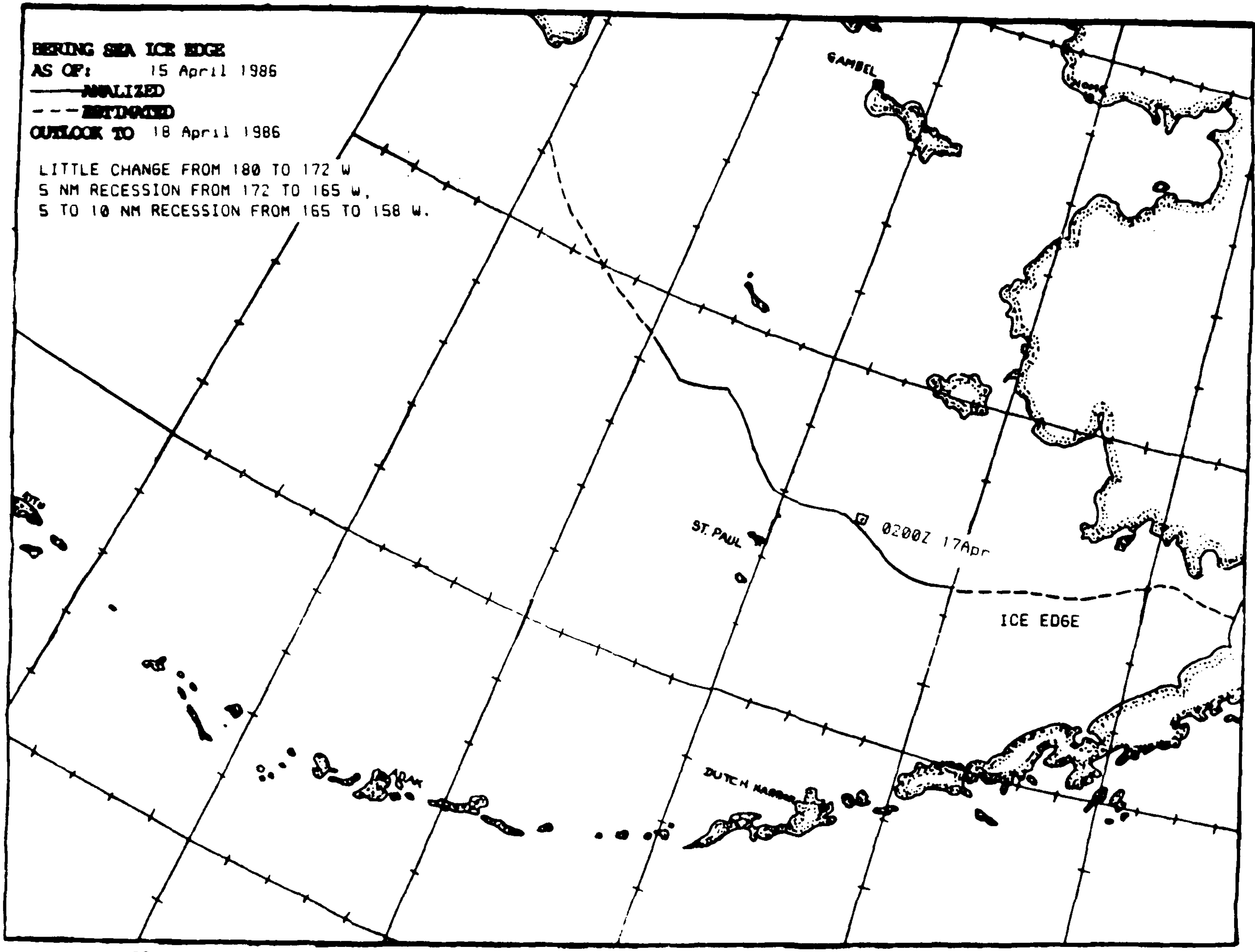


Figure 11 - USCGC Polar Sea 17 April 1986 observed ice edge locatio: compared with Bering Sea Ice Edge Forecast.

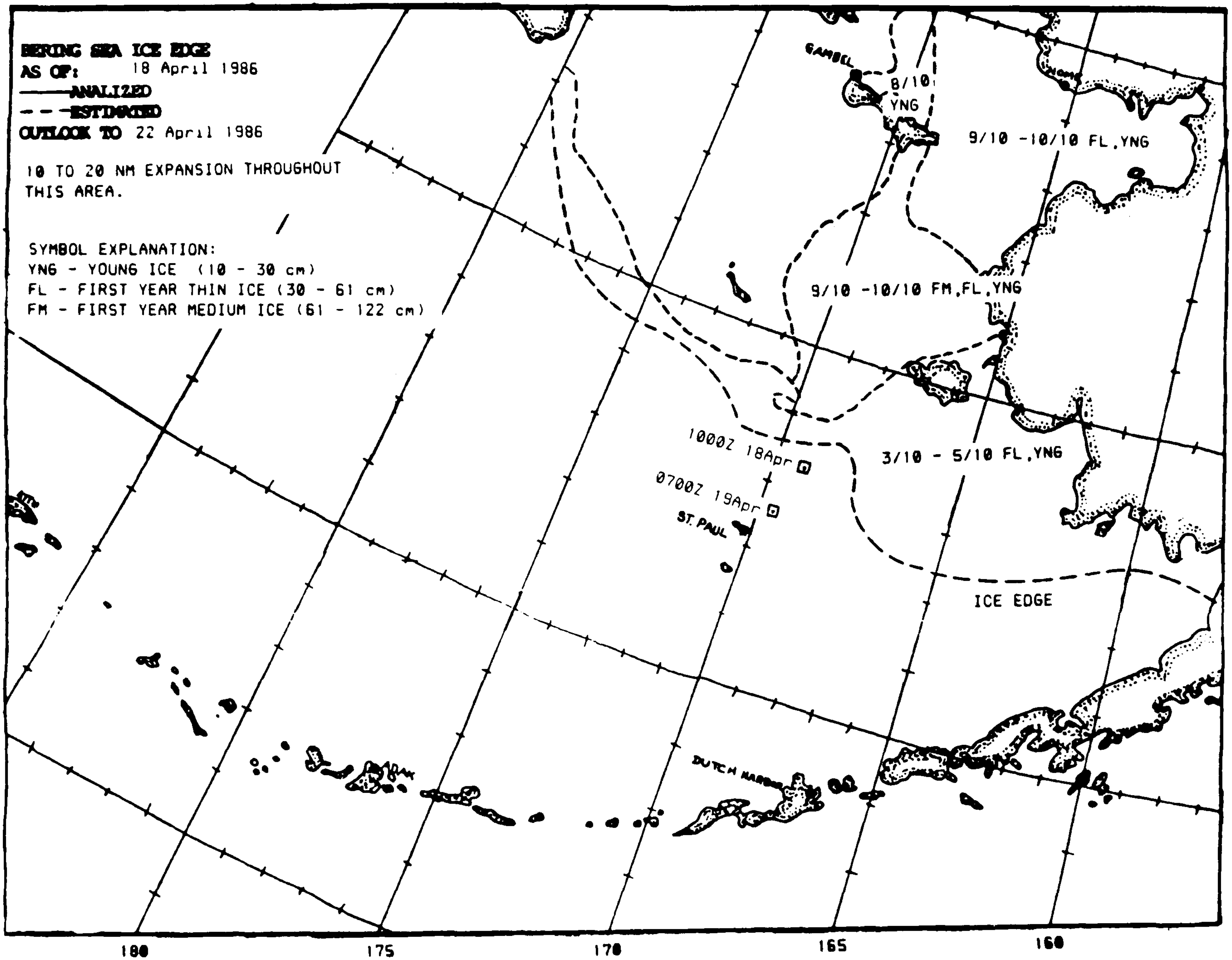


Figure 12 - USCGC Polar Sea 18 and 19 April 1986 observed ice edge location compared with Bering Sea Ice Edge Forecast.

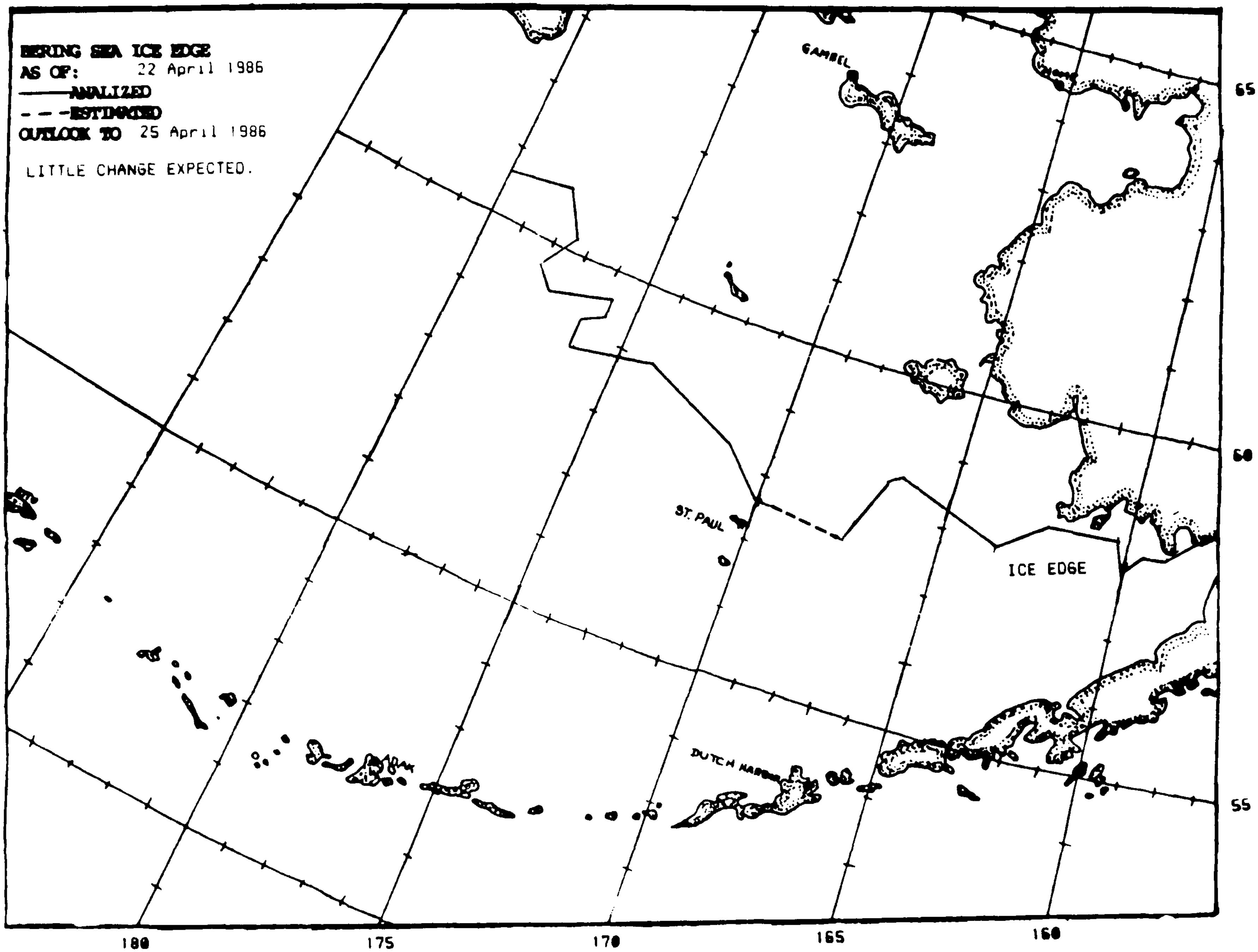


Figure 13 - Bering Sea Ice Edge Forecast for 22 to 25 April 1986.

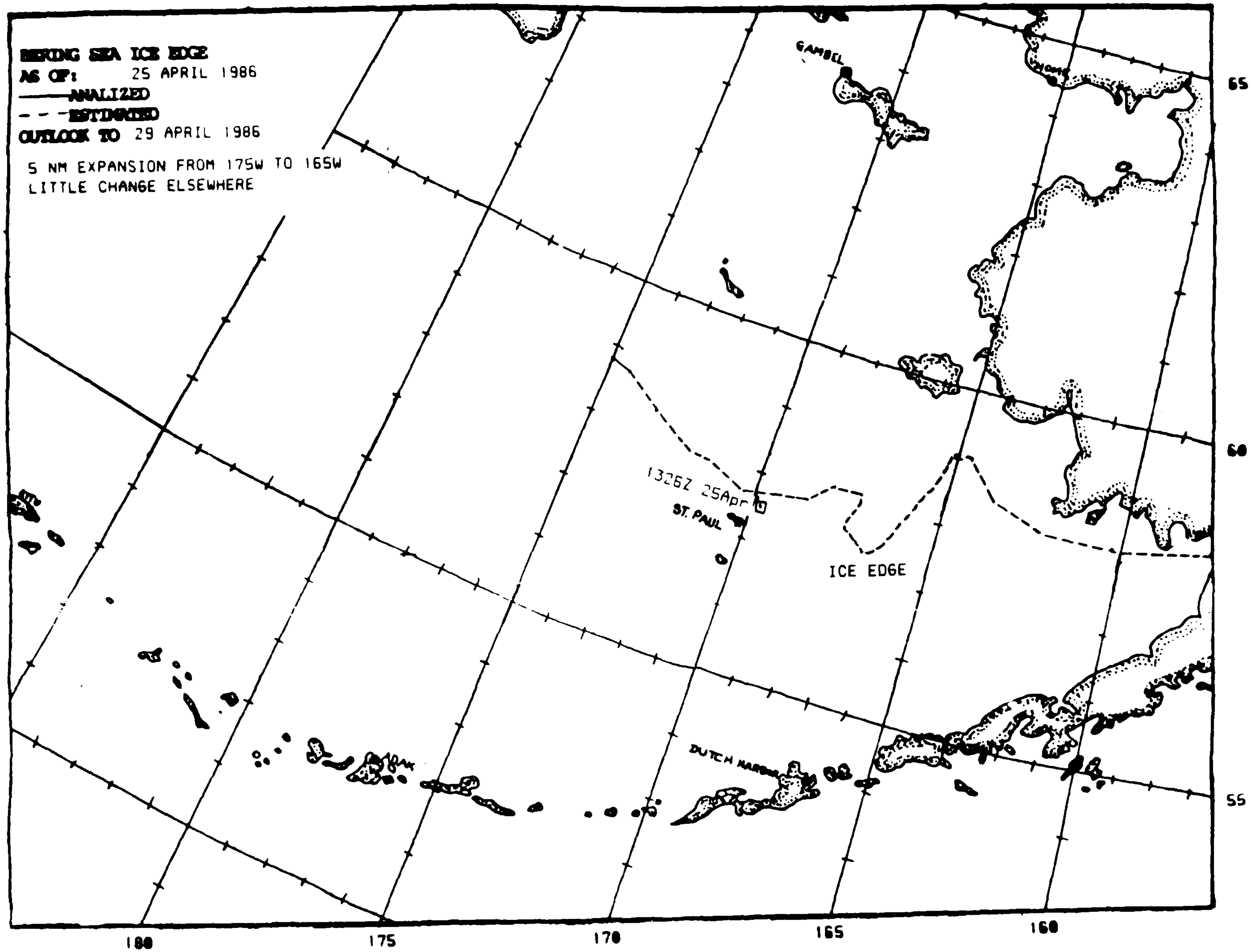


Figure 14 - USCGC Polar Sea 25 April 1986 observed ice edge location compared with Bering Sea Ice Edge Forecast.

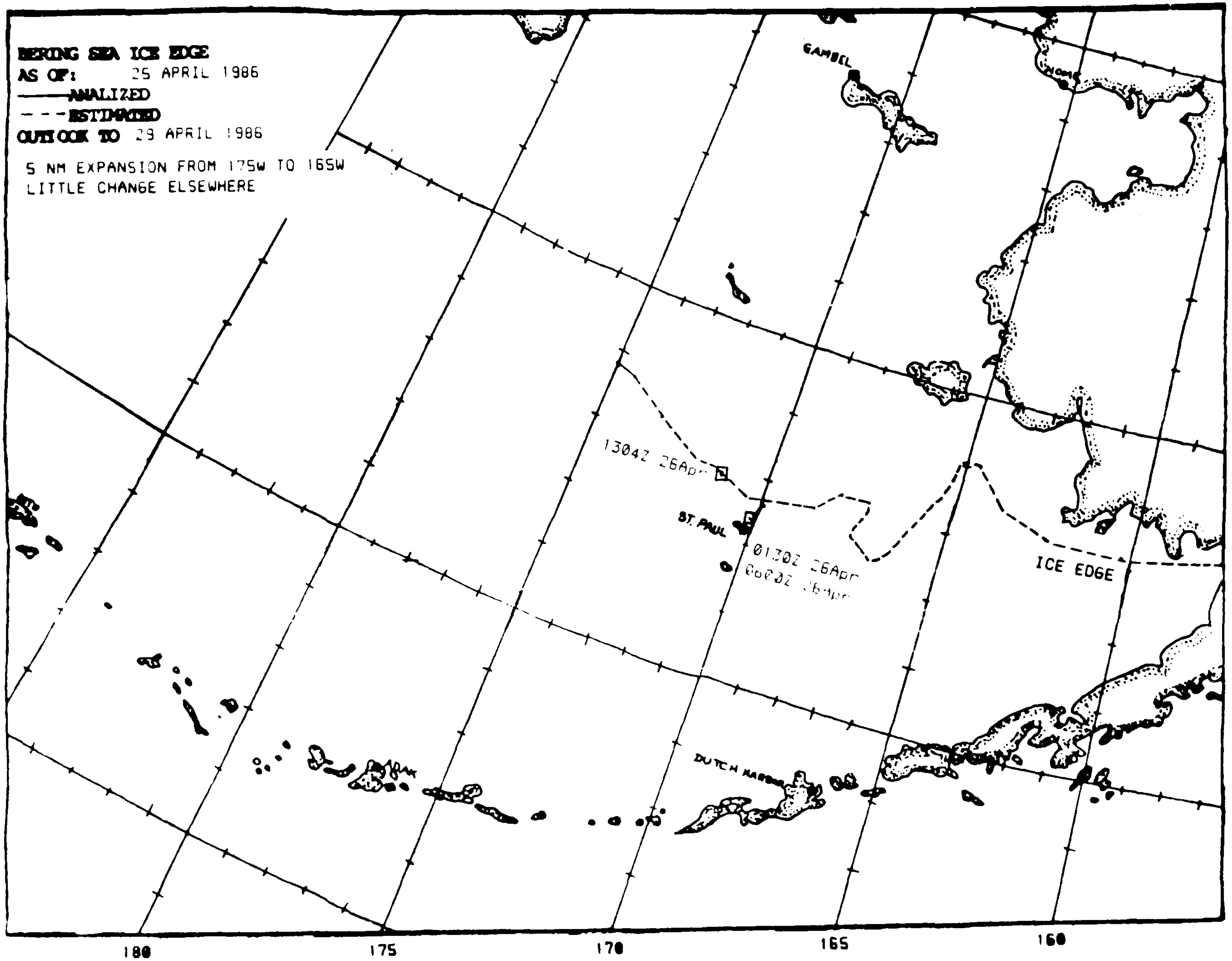


Figure 15 - USCGC Polar Sea 26 April 1986 observed ice edge location compared with Bering Sea Ice Edge Forecast.

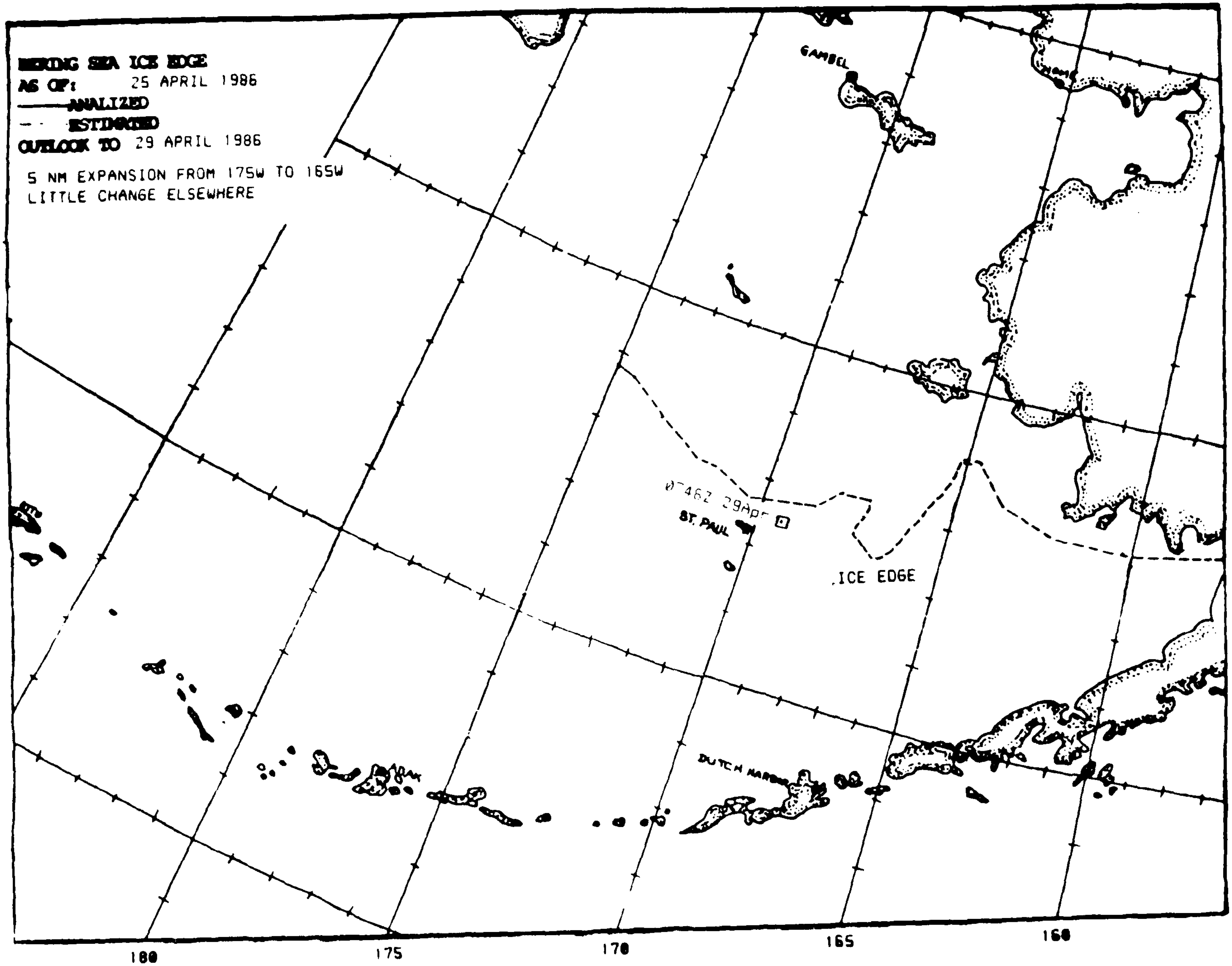


Figure 16 - USCGC Polar Sea 29 April 1986 observed ice edge location compared with Bering Sea Ice Edge Forecast.

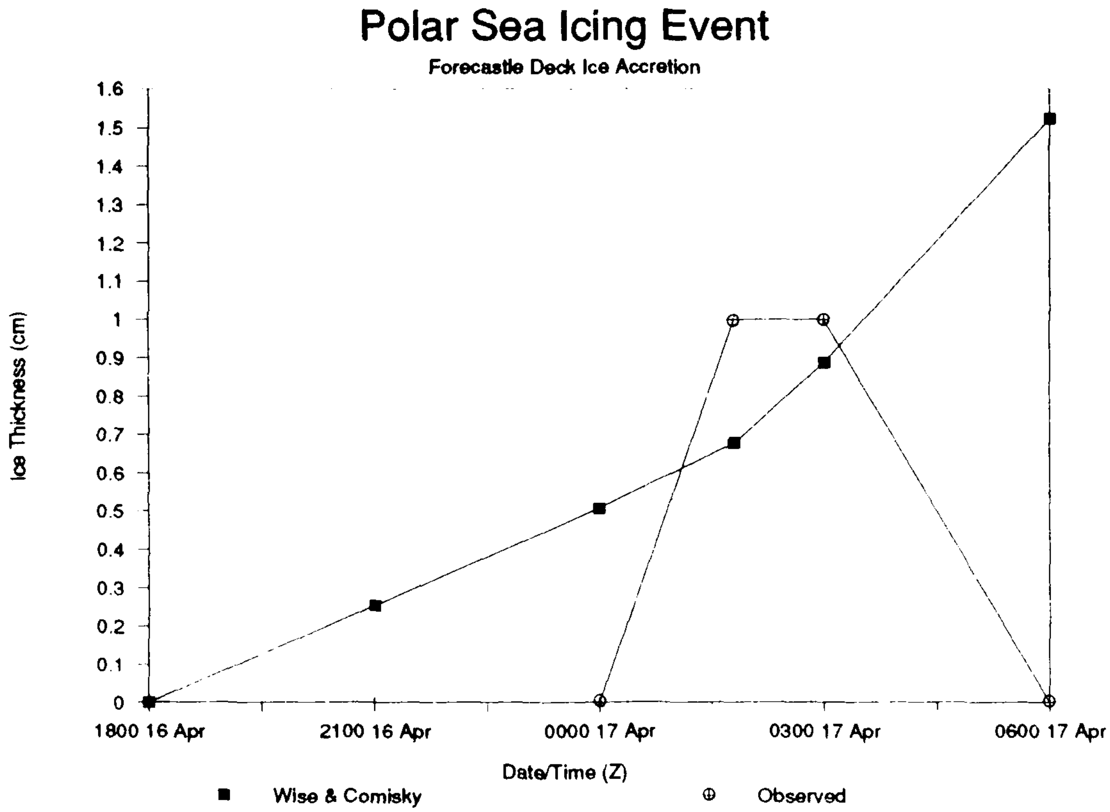


Figure 17 - USCGC Polar Sea 17 April 1986 observed ice accretion compared to Wise and Comisky prediction.

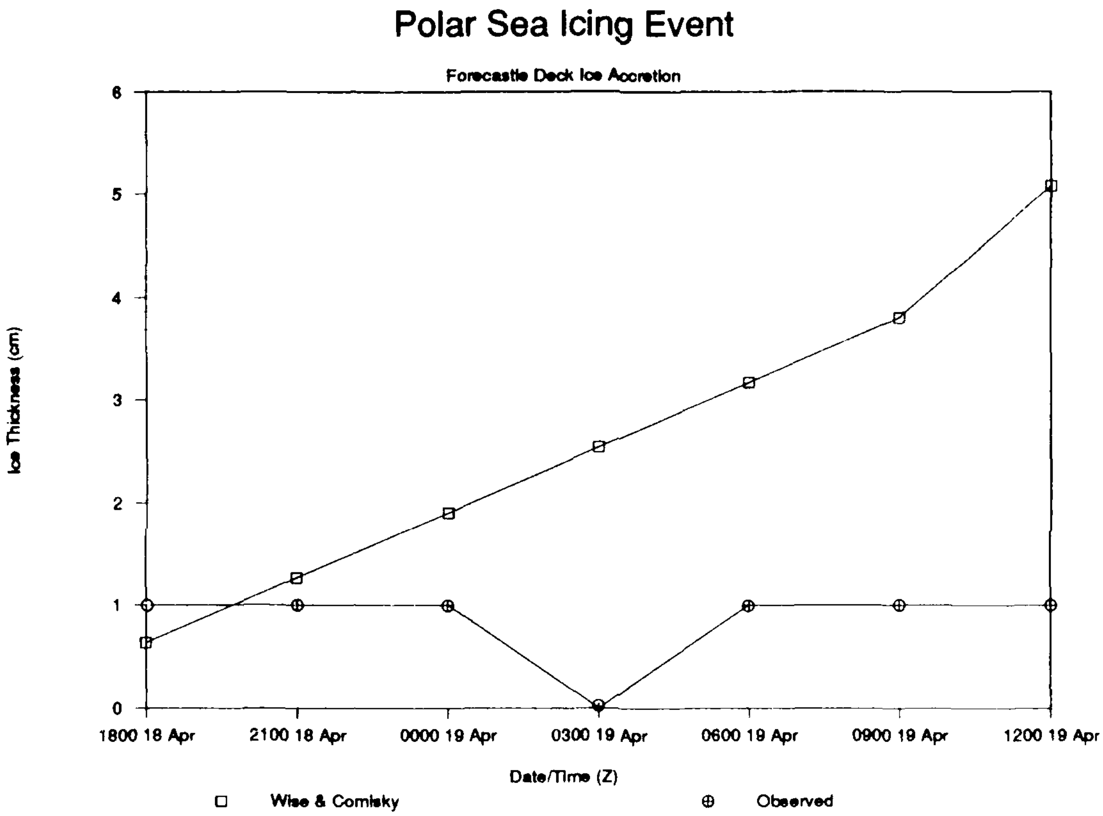


Figure 18 - USCGC Polar Sea 18 and 19 April 1986 observed ice accretion compared to Wise and Comisky prediction.

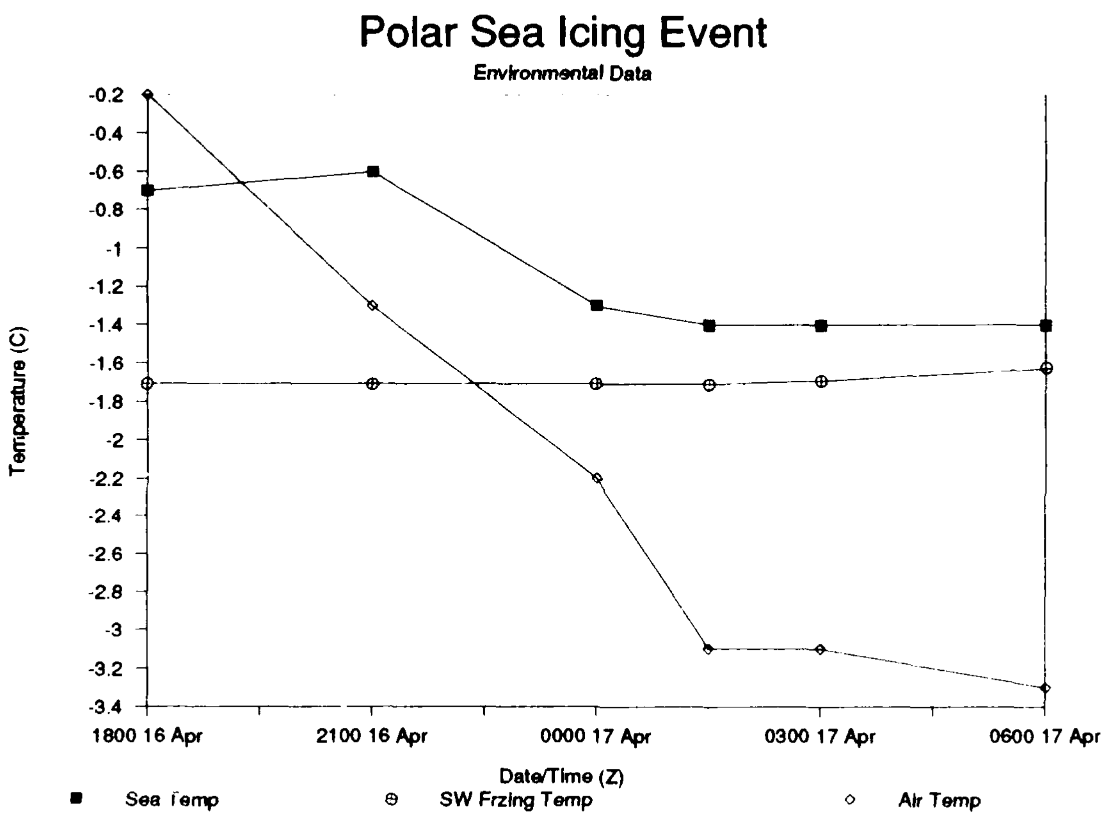


Figure 19 - Bering Sea Air and Sea temperatures during 17 April icing event.

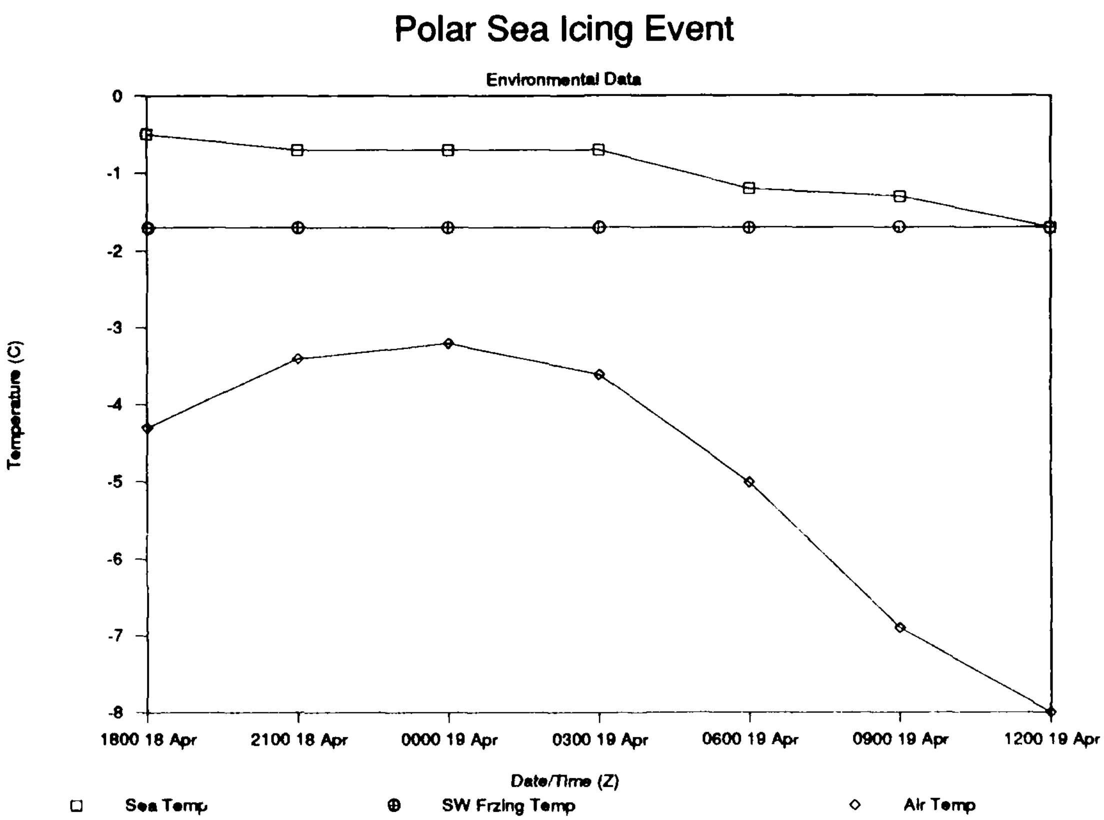


Figure 20 - Bering Sea Air and Sea temperatures during 18 and 19 April icing event.

Table 1. Delft wave buoy characteristics (from Reference 2).

Working lifetime	8 hours
Transmitted power	1.5 watts
Transmitter frequency	27.7 MHz
Buoy diameter	0.43 m
Length of antenna	1.5 m
Mass of buoy	10.2 kg
Mass of stabilization weight	10.2 kg
Max deployment height	15 m
Max ship speed during deployment	24 knots
Wave data provided after analysis	Nondirectional point spectra

Table 2. Delft wave buoy measurements taken aboard USCGC POLAR SEA in the northeastern Pacific Ocean and the Bering Sea in April 1986.

Buoy Measurement	Launch Position	Forecast Grid Point	Distance to Grid Point (nmi)	Direction to Grid Point (from measurement)	Launch Time	Forecast Time	Measurement Time Difference (hours)	Ice Concentration (tenths)
1	Lat:51.6N λ: 135.9W	Lat:52.5N λ: 137.5W	91.3	WNW	18Z 9 Apr	12Z 9 Apr	+6	0
2	Lat:53.0N λ: 144.7W	Lat:52.5N λ: 145.0W	31.9	SSW	21Z 10 Apr	00Z 11 Apr	-3	0
3	Lat:53.9N λ: 153.7W	Lat:55.0N λ: 152.5W	79.0	NE	02Z 12 Apr	00Z 12 Apr	+2	0
4	Lat:56.5N λ: 167.4W	Lat:57.5N λ: 167.5W	60.1	N	00Z 16 Apr	00Z 16 Apr	0	0
5	EQUIPMENT	MALFUNCTION	NO DATA					NA
6	Lat:58.5N λ: 171.2W	Lat:57.5N λ: 170.0W	71.1	SE	18Z 27 Apr	12Z 27 Apr	+6	7
7	Lat:58.5N λ: 171.2W	Lat:57.5N λ: 170.0W	71.1	SE	20Z 27 Apr	00Z 28 Apr	-4	7
8	Lat:57.5N λ: 170.0W	Lat:57.5N λ: 170.0W	0	on point	03Z 29 Apr	00Z 29 Apr	+3	7

Table 3. Location of observed ice edges recorded during April 1986 deployment of USCGC POLAR SEA.

Date	Time (Z)	Latitude (N)	Longitude (W)
17 April	0200	57°57'	167°56'
18 April	1000	58°20'	169°10'
19 April	0700	57°36'	169°39'
25 April	1326	57°32'	169°48'
26 April	0130	57°22'	170°09'
26 April	0600	57°24'	170°10'
26 April	1304	57°46'	171°16'
29 April	0748	57°27'	169°28'

Table 4. Comparison of observed and forecasted ice edges recorded during April 1986 deployment of USCGC POLAR SEA in the Bering Sea.

Date	Time (Z)	Comparison Remarks
17 April	0200	Observed ice edge falls within 5 nmi recession predicted by ice forecast
18 April	1000	Observed ice edge falls 15-20 nmi south of estimated ice edge
19 April	0700	Observed ice edge falls 30 nmi south of forecasted ice edge after expansion
25 April	1326	Observed ice edge falls 10 nmi south of forecasted ice edge
26 April	0130	Observed ice edge falls 5-10 nmi south of forecasted ice edge after expansion
26 April	0600	Observed ice edge falls 5-10 nmi south of forecasted ice edge after expansion
26 April	1304	Observed ice edge falls on forecasted ice edge
29 April	0748	Observed ice edge falls 10 nmi south of forecasted ice edge after expansion

Table 5. Period of possible icing of ships (from Reference 6).

Water Areas	Number of Cases	Icing Period
Northwestern Atlantic	85	December 15 - March 15
Norwegian and Greenland seas	109	December 15 - March 31
North Atlantic	63	December 15 - April 15
Barents Sea	390	January 1 - March 15
Baltic Sea	21	December 15 - February 28
Baffin Sea, Hudson Bay	7	December 1 - March 31
Newfoundland area	15	January 1 - March 15
Bering Sea	185	December 1 - March 31
Sea of Okhotsk	337	December 1 - March 31
Sea of Japan	226	December 1 - February 28
Northwest Pacific	183	December 15 - March 15
Arctic seas (Kara, Laptev, East Siberia, and Chukchi seas)	74	June 15 - November 15

Table 6. Bering Sea ice accretion data taken aboard USCGC POLAR SEA from 16 to 17 April 1986.

Date	Time (Z)	Forecasted Ice Accretion Minimum Thickness (cm)	Observed Ice Accretion Thickness (cm)
16 April	1800	0.0	0.0
	2100	0.3	0.0
17 April	0000	0.5	0.0
	0200	0.7	1.0
	0300	0.9	1.0
	0600	1.5	0.0

Table 7. Bering Sea ice accretion data taken aboard USCGC POLAR SEA from 18 to 19 April 1986.

Date	Time (Z)	Forecasted Ice Accretion Minimum Thickness (cm)	Observed Ice Accretion Thickness (cm)
18 April	1800	0.6	1.0
	2100	1.3	1.0
19 April	0000	1.9	1.0
	0300	2.5	0.0
	0600	3.2	1.0
	0900	3.8	1.0
	1200	5.1	1.0

Table 8. Bering Sea environmental data related to ice accretion taken aboard USCGC POLAR SEA from 16 to 17 April 1986.

Date	Time (Z)	Seawater Temperature (C)	SW Freezing Temperature (C)	Air Temperature (C)	Wind Speed (knots)
16 April	1800	-0.7	-1.7	-0.2	21
	2100	-0.6	-1.7	-1.3	28
17 April	0000	-1.3	-1.7	-2.2	26
	0200	-1.4	-1.7	-3.1	28
	0300	-1.4	-1.7	-3.1	28
	0600	-1.4	-1.6	-3.3	23

Table 9. Bering Sea environmental data related to ice accretion taken aboard USCGC POLAR SEA from 18 to 19 April 1986.

Date	Time (Z)	Seawater Temperature (C)	SW Freezing Temperature (C)	Air Temperature (C)	Wind Speed (knots)
18 April	1800	-0.5	-1.7	-4.3	29
	2100	-0.7	-1.7	-3.4	34
19 April	0000	-0.7	-1.7	-3.2	32
	0300	-0.7	-1.7	-3.6	31
	0600	-1.2	-1.7	-5.0	30
	0900	-1.3	-1.7	-6.9	33
	1200	-1.7	-1.7	-8.0	38

REFERENCES

1. Jeck, R.K., "Superstructure Icing: Non-Suitability of Current Forecasting Aids for Navy Ships," Naval Research Laboratory Memorandum Report 5377, Washington, D.C. (Jul 1984).

2. Buitenhek, M. and J. Ooms, "An Updated Design of a Disposable Wave Buoy," Delft University of Technology Report No. 463, Delft, Netherlands (1978).

3. Earle, M.D. and J.M. Bishop, "A Practical Guide to Ocean Wave Measurement and Analysis," ENDECO, Inc., Marion, Mass. (1984).

4. Naval Polar Oceanography Center/Joint Ice Center, 1984, Ice Observation Handbook (1984).

5. Naval Polar Oceanography Center/Joint Ice Center, Presail Information Booklet for Units Deploying to the Arctic or Antarctic.

6. Panov, V.V., "Icing of Ships," Polar Geography 2(3) Translated from Trudy Arkticheskogo i Antarkticheskogo nauchno-issledovatel'skogo instituta, Vol. 334 (1976).

7. Ono, Nobuo, "Studies of Ice Accumulation on Ships, Part II," Teion Kagaku (Low Temperature Science), Series A (Physical Sciences), No. 22 (Defense Research Board translation T 94 J) (1964).

8. Stallabrass, J.R., "Trawler Icing: A Compilation of Work Done at N.R.C.," Ottawa, Canada, National Research Council Canada, No. 19372 (1980).

9. Borisenkov, E.P. and V.V. Panov, "Basic Results and Prospects on Hydro-Meteorological Conditions of Shipboard Icing." Investigation of the Physical Nature of Ship Icing by E.P. Borsenkov et al., U.S. Army Cold Regions Research and Engineering Laboratory, Draft Translation 411 (1974).

10. Shekhtman, A.N., "Hydrometeorological Conditions in the Icing-Up of Vessels at Sea," Naval Scientific and Technical Information Center (U.K.), Translation No. 2311 (1971).

11. Shekhtman, A.N., "The Probability and Intensity of the Icing-Up of Ocean-Going Vessels," Naval Scientific and Technical Information Center (U.K.), Translation No. 2312 (1971).

12. Bales, S.L., L.R. Elliott, and W.L. Thomas, "Degradation of Surface Ship Operation in Arctic/Cold Weather Environments," U.S. Navy Symposium on Arctic/Cold Weather Operations of Surface Ships (Dec 1985).

13. Wise, J.L. and A.L. Comiskey, "Superstructure Icing in Alaskan Waters," NOAA Special Report, Pacific Marine Environmental Laboratory, Seattle, WA (PB 81-135188) (1980).

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